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Notes on Some Materials Research in Germany: I

H. A. Lipsitt

27 December 1967

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NOTES ON SOME MATERIALS RESEARCH IN GERMANY: I

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NOTES ON SOME MATERIALS RESEARCH IN GERMANY: I

INTRODUCTION

Because Germany is so large and so heavily industrialized, it would be fatuous for one to presume to keep track of all the materials research carried on in that country. It is my intent, however, to visit Germany several times and to produce a series of reports which may overlap, but are not necessarily fully comprehensive. On this trip, I was able to visit the following institutions:

1. Max Planck Institut für Eisenforschung, Düsseldorf

2. Metallaboratorium, Metallgesellschaft AG, Frankfurt

3. Leichtmetall-Forschungsinstitut, Vereinigte Aluminium-Werke AG, Bonn

4. Batelle Institut e.V., Frankfurt

THE MAX PLANCK INSTITUT FÜR EISENFORSCHUNG, DÜSSELDORF

This Institute is typical of other research institutes in Germany. It consists of reasonably modern, well-located buildings, and I would say that in the areas in which the Institute is supposed to be working, it is reasonably well equipped. The main difficulty, in my mind, is that the research is essentially restricted to steel, but more than that, it is virtually restricted to technical steels -- to real materials, often alloyed with many things which make a quantitative investigation of the relations of structure and properties practically impossible.

I found, on the other hand, much to my pleasure, that the Director, Prof. W. Oelsen, although he is 62, is very modern in his ideas. In fact, the idea about which I was most pleased was his belief that the director of an institute should maintain his own research interests (and Oelsen has done that). He also believes that the director of an institute should not be (in the old German tradition) the absolute monarch, the absolute final word in all respects, and should not put his name on all papers coming out of the institute, the research for which he has had no direct connection. These ideas are complementary in that a director who maintains his own research program and international reputation does not need to rely on the publications of his institute for prestige.

The Institute generally concerns itself with three kinds of research. The first is characterized as being fundamental, but by fundamental they mean research not under the day-to-day influence of the steel companies of Germany. The second kind, as characterized by them, is applied research. Generally, this is done under contract with either a German steel company or with the Federal government. The third kind of work performed is trouble shooting. This, again, is mainly with steel companies and the object is to solve the problem quickly and recommend a solution.

The money for this research, in the main, comes from the iron and steel industry in Germany. This is not in the form of direct contracts for a particular piece of research, but rather in indirect, general support of the research of the Institute. The second type of support, amounting to about 30% of the total, comes from the Max Planck Society, and finally another 20-30% of the operating funds comes directly from a particular company for a given research effort. Altogether, there are 270 people employed in the Institute, about 60 of whom are scientists, approximately 120 technicians, and the rest administrative and support staff, secretaries and apprentices. Thus, roughly 20-25% of the total staff is of an administrative nature, almost half are technicians and the other quarter are the scientists themselves.

The Institute is divided into five Departments. The Chemical Department does routine chemical analysis, the isolation of phases (second phases from steel) and spectroscopic work. The Physical Department does X-ray work, magnetic studies, constitution of steels, TTT diagrams, constitution-temperature diagrams, and the like. The Metal Physics Department, under the leadership of Dr. A. Kochendörfer, does electron microscopy and low temperature studies of the properties of materials. The Technical Department takes care of the furnaces and the open hearth studies, rolling, wire drawing and general metals processing. The Mechanical Department is divided into three sub-departments studying static and creep properties, fatigue and theoretical mechanics and fracture. Oelsen, in addition to being Director of the Institute, has a research group of his own which is not really a department, but is, nevertheless, concerned with study of slags and the physical chemistry of steel making.

Dr. Kochendörfer and Dr. W. Pitsch were away when I visited the Institute, so I was only able to see Dr. Oelsen, Dr. M. Hempel, in charge of the fatigue group, and Dr. P. L. Ryder of the electron microscopy group. Hempel runs a large group which handles eight or nine fatigue research programs simultaneously. His papers (usually published in Archiv für das Eisenhüttenwesen) contain a tremendous amount of data. Although the data are such that interpretation in depth is normally not possible, such design data are also necessary and valuable.

In the past two years Hempel has published several papers describing his work on the influence of melting practice on the fatigue behavior of bearing steel (no marked effect noticed between a good air melted and a vacuum melted steel); the fatigue strength of welded titanium (no apparent connection between the path of fracture and the pores along the weld/metal boundary?); the influence of heat treatment and testing variables on the fatigue strength of Ti-5 Al-2.5 Sn and Ti-GAl-4 V (a contract supported program); hot tensile and fatigue behavior of a Co-20 Cr-15 W-10 Ni alloy in the range 800-1200°C; the metallography of crack formation at inclusions in a Cr-Mo steel; and the fatigue behavior of various molded carbon materials.

Hempel is currently studying the fatigue and stress-rupture behavior of an 0.008 C-15 Ni-15 Cr steel (containing some Mo and Nb) at temperatures in the range 550-650°C. He finds that at long times ($\sim 10^5$ hours) the stress-rupture and fatigue curves meet, indicating that for very long exposure it is not important if the stress applied is static or dynamic.

He is also investigating the influence of some steel-making practices on fatigue. He has two plain carbon steels with nominal tensile strengths of 52,000 and 74,000 psi. He is studying the effects of oxygen melting and of rimming vs. killing on the notched and unnotched fatigue strength of these steels as they are produced in three different steelworks! He has found, thus far, that oxygen steelmaking practice produces a material showing a fatigue limit higher by 1500-3000 psi and with somewhat narrower statistical scatter.

He also has a large thick-walled tube of (the German equivalent of) SAE 4340 steel from which he has taken longitudinal, transverse and radial specimens. Half the specimens have been heat-treated to produce a yield stress of 114,000 psi and the rest to 185,000 psi. The steel has a higher sulfur content inhomogeneously distributed, and it is expected that the influence of inclusions on the fatigue statistics will be far more pronounced in the higher strength condition.

The last of Hempel's current investigations is a study of the fatigue and stress-rupture behavior at 700°C of Nichrome (80 Ni - 20 Cr) with addition of Co, Mo, W, Ti and Nb. He has found that the addition of Co raises the fatigue strength more than the stress-rupture strength, whereas the reverse is true for the other elements listed.

Dr. P. L. Ryder is an Englishman who did his PhD in Cambridge with Dr. J. Nutting, then worked for Dr. R. F. Mehl in Zurich, and now seems to be happily settled in Düsseldorf working with Dr. W. Pitsch in the electron microscopy group. They have two (Siemens) electron microscopes, and new ARL electron probe microanalyzer, and all of the necessary ancillary equipment.

Some recent research of this group includes a study of the reverse martensite transformation in an Fe-32.5 Ni alloy. They found that the reverse martensite transformation essentially stops occurring in the temperature range 180-300°C. Above 300°C the transformation again occurs, but it is now a diffusion-controlled process rather than a shear process, and the rate controlling step appears to be the diffusion of Ni. Unfortunately this cannot be confirmed experimentally with a microprobe, because the Ni gradient would be well within 1μ from the martensite plates -- this looks like an ideal problem for an electron microscope with a velocity analyzer. They have recently built a Kossel camera for their microprobe and have used this to determine the habit planes of the Fe-Ni martensite (Acta Met. 15, 1894 (1967)).

Ryder is currently working on a computer program for determining foil orientation from an electron diffraction pattern. This requires two orthogonal reference wires in the electron beam; the input data used are the indices of two strong reflections from one zone and one spot from another and the angle between one spot and the reference axis; the output is the orientation relationships to all three axes, one of which is the electron beam. This seems to be the only sane way to study the orientation relationships of (say) pearlite (both ferrite and cementite) with respect to both the austenite grain into which it is growing and the adjacent austenite grain.

THE METALLABORATORIUM, METALLGESELLSCHAFT AG, FRANKFURT

The Metallgesellschaft is a large holding company with control over a great number of individual companies covering a wide scope of interests. The activities of the Metallgesellschaft include chemicals, shipping and engineering, as well as processing and refinement of Zn, Sn, Pb, Ag, Li, Cu, Fe, Mn, Zr and their alloys. The company's central headquarters is in Frankfurt, as are the four central research laboratories: The Colloids Laboratory; The Inorganic Chemistry Laboratory; The Analytical Laboratory; and the Metallaboratorium. There are 1200 employees located in Frankfurt, including the central staff; the total laboratory staff is about 250, about 70 of whom are in the Metallaboratorium. Of these 70 about 15 are scientists, six are apprentices and most of the rest are technicians, yielding a technician-scientist ratio of about 3:1.

The research work is mainly confined to a searchfor new or better products or better ways of doing things as well as maintaining over-all cognizance of the quality control of materials produced by the consortium.

The previous director of the Metallaboratorium, Prof. Dr. Max Hansen, retired about 18 months ago. Dr. Peter Wincierz was named to be his successor. Hansen, however, is still very much in evidence as a member of the Board of Directors of many of the individual companies that form the Metallgesellschaft, and because he lives near Frankfurt, comes in every once in a while to watch over things. The recently published research of the laboratory, beginning about a year ago, consists of such things as an investigation of the influence of neutron irradiation on the properties of Zn-Nb-Sn alloys; the influence of the precipitation and the solution heat treatment temperature on the texture and hardness of Al-Mg-Si-Mn alloys; a paper on the corrosion-fatigue of copper and copper alloys as compared to the aluminum bronzes; a paper on the oxidation of molten zinc and the influence of added elements on the oxidation rate; and a paper on the binary phase diagram of the system In-Ga.

They have recently published a paper on microstructures in Cu-Ni-Si alloys and the influence of heat treatment on the structure. The precipitation in the alloy containing 2% silicon was investigated by microscopy,

diffraction and hardness tests. The sole aging temperature used was 475°C, the technically used aging temperature. They found that the age hardening is due to second-phase particles which are precipitated in a fine dispersion and are apparently preferentially oriented in the matrix. The particles seem to be between 50 and 100 Å in diameter and have between 200 and 350 Å spacing between them. It was found that the precipitated phase did not correspond to any of the known intermetallic Ni-Si compounds. They also found in this material, following the first precipitation, another microstructural change which resembled discontinuous precipitation. When this was allowed to occur, the finely dispersed precipitates first dissolve and then reprecipitate in this coarser dispersion (Z. Metallkunde 57, 521 (1966)).

Also recently published was a similar study on the temperature dependance of the mechanical properties, the microstructure and the oxidation behavior in an arsenic-containing aluminum bronze, the material being approximately Cu-5Al with minor amounts of other things. They were able to show for the first time that the mechanism of the usual high strength of these alloys is due to a very fine precipitate which can only be seen in the electron microscope. The precipitate was not able to be identified; however, they were able to show that the lattice parameter is 6.25 Å, which is quite large. The fatigue data, for example, show that the addition of a very minor amount of arsenic raises the fatigue strength about 7000 psi for a life of approximately 2 x 10^6 cycles, a very significant increase. As well, it is indicated that even at 200°C the fatigue properties of the arsenic containing bronze are virtually the same as those of the arsenic free bronze at room temperature. With continued aging at the precipitation temperature the very small particles begin to grow and are seen to be crystallographic. They generally lie along the ⟨110⟩ direction in the lattice.

Finally, using the electron microscope and measuring from dislocation nodes, the group were able to verify very nicely the stacking fault energy measurements of Howie and Swann (Metall 21, p. 102 (1967)). Some of their current results with electron microscopy indicate that a great many stacking fault tetrahedra are found in Cu-Sn alloys when these materials are subject to fatigue stressing, whereas such tetrahedra are not found if the alloy is merely quenched and aged.

Another investigation which has just been completed and will be published at the beginning of the year in Metall is a full investigation by several of the daughter companies of the firm which considers the impact and fatigue properties of some two-phase bronzes which they find do not show any notch sensitivity. In fact, because of the nature of the usual definition of notch sensitivity, it may be said that these materials show a negative notch sensitivity. They have also done, and are doing extensive investigation on the segregation of elements in nodular iron, using their electron microprobe. They also have some aluminum alloys

onto which a layer of pure aluminum has been roll bonded, which are showing a great many bubbles and unbonding of the soft aluminum surface layer, and they are attempting to figure out the cause of this.

In the field of Cu alloy development they are looking for a copper alloy with increased strength. In fact, they wish to obtain a rupture strength of 140,000 psi. This research is based on the bronzes which yield a reasonably strong martensite that is then tempered back to give some ductility. They are also trying to do this by strengthening existing materials by precipitation, starting with Cu-Ni and adding silicon, or by starting with Cu-Ti or Cu-Zr alloys. In general, this is an attempt to find alloys to fill the strength gap between the conventional precipitation hardened materials and the dispersion hardened materials, the reason being that the dispersion hardened materials are too expensive.

In the aluminum alloy field these people are very much concerned over the poor stress-corrosion behavior of Al-Zn-Mg alloys. They have found that the addition of silver to this alloy, which makes the material more resistant to stress corrosion, causes a swelling type of corrosion (separation of one layer after another of the material) to occur in the heat affected zone near a weld, so that although Ag additions may be beneficial, they do not help in cases where a reheat-treatment of the material after welding cannot be performed in the field. It is interesting that as an intermediate solution zinc is flame sprayed just onto the heat affected zone in these materials, and this seems to solve the problem.

They are also doing research to find materials which are capable of being machined more easily, essentially using radioactive tracer techniques to study tool wear as a guide to tell them if they have improved the machinability of the alloy. They have embarked on a long-term program in this regard, first to learn the machine variables and their influence on current alloys and then to see how they can modify the composition of the alloys to determine whether the machining can be improved. The primary goal in this work is to determine the variables that most influence the scatter in machinability and to see if these can be controlled.

In zirconium research, they have been studying the textures in zircaloy, varying the texture by plastic deformation in an effort to minimize the amount of hydrides which lie along the radial direction in a pipe and to maximize the number of tangential hydrides (see also Trans. Met. Soc. AIME 239, 1659 (1967)).

This Laboratory is also beginning two investigations in the realm of composite materials. They are attempting to put circumferential glass filaments into Al pistons, since the Al casting alloys are brittle and do not have very high thermal shock resistance. They hope that the presence of filaments will tend to deflect any cracks (that might start) along the relatively weak glass-metal interface and thereby greatly reduce crack

propagation rates through the piston. They are also interested in techniques for raising the strength of maraging steel sheet, probably by roll bonding a sandwich, containing glass or boron filaments.

In general, this seemed to be a very tightly run research organization. The Director seemed to be aware of the work going on, and it was quite clear that this was a research laboratory which did, in fact, work on the problems and attempt to find solutions to the problems of the daughter companies for which it was the central research laboratory.

The old friends of Prof. Dr. Hansen will be pleased to hear that although he apparently had some trouble with his heart a couple of years ago, he has recovered from that and appears to be in very excellent health and was certainly in very excellent spirits.

THE LEICHTMETALL-FORSCHUNGSINSTITUT, VEREINIGTE ALUMINIUM-WERKE, BONN

This Laboratory, the Light Metal Research Institute of the United Aluminum Works, is located in Bonn and is the central research laboratory for this large, fully integrated aluminum company. The holding company controls several bauxite mining concerns, the facilities for complete processing of the ore and for the casting and forming of the metal and its alloys.

The Director of Research of this Laboratory is Prof. Dr. Wolfgang Gruhl. There are about 150 people employed in the Institute, who are responsible for research, development and production quality control on all phases of production -- the ore, the electrodes, the alloys, the heat treatment, the casting, forging, etc. The Laboratory is divided into several groups. There is an Analytical Group which has the responsibility for the analytical equipment in all of the Works laboratories scattered throughout the country, including its maintenance and supplying the standards for it. This I thought was an interesting function for a research laboratory, and certainly an effective means to maintain a single standard of quality in a widely dispersed operation. In addition, there are groups working on casting problems, stress corrosion problems, alloy development, trouble shooting, etc.

The work of the Laboratory is generally divided into three parts. Gruhl said that about 50% of the work comes directly from the plants, and this is in the form of trouble shooting for which a solution has to be determined very quickly and put into effect. About 20% of their work is problems directly from the customers. About 30% of the work of the entire Institute is research which consists mainly of studies on alloy development, new casting techniques and stress-corrosion. One man to whom I talked does all trouble shooting, another 100% research, and the others do various proportions of each; apparently the average is about 30% research.

They have recently developed an alloy exactly like our 7075 aluminum alloy, except that it contains 1% Cu instead of 2%. Although this alloy is not as strong as 7075, it has improved resistance to stress-corrosion considerably. For this alloy they specify a guaranteed minimum 0.2% ys of 64,000 psi and a UTS of 74,000 psi; typical values are 68,000 and 77,000 psi, respectively. These properties are achieved using a two-step aging treatment which consists of 24 hours at a temperature of 120°C, and then a further three to five hours at a temperature of 180°C. They find that with this heat treatment the strength of the material is only marginally less than if it were given the ordinary treatment of 24 hours at 120°C, the standard treatment for 7075 in the US. They also find, as have others in England and Australia, that with a very small addition of silver they are able to quench directly from the solution heat treatment temperature to the aging temperature of 170°C and achieve essentially the same properties as they are able to in the ordinary alloy given the two-step heat treatment. In Germany, for ordinary construction purposes, they favor the use of a two-step heat treatment on a 1% copper bearing Al-Zn-Mg alloy rather than the use of silver, even though the silver gives them a wider acceptable range of heat treatment temperature and eliminates one step in the heat treatment. They developed this two-step heat treatment primarily for their weldable materials which have been used extensively for support in mine shafts. These supports are under internal hydraulic pressure in a humid atmosphere and have been in place now, in many cases, for as much as five years without a single failure.

They have also developed an alloy containing 4% zinc, 1/2% magnesium and a little chromium, which they find has the same extrusion characteristics as our alloy 6063. This material naturally ages to a yield stress of 34,000 psi: it is nonsusceptible to stress-corrosion and is especially good, they feel, because its extrusion temperature is lower than for 6063; 400°F instead of 500°F, and the temperature range is not so critical. Also, they do not need to homogenize the ingot before extrusion and, of course, the maximum strength is achieved without artificial aging, all of which saves money. They are very pleased with this material because of its low cost and low stress-corrosion susceptibility, and will be publishing a paper about it in the March issue of the German journal Metall.

They have also developed a weldable alloy which contains a little bit less magnesium than one of their standard alloys (4.5% Zn - 1.2% Mg), no copper, and yields a 0.2% proof stress of 42,000 psi (28 to 41 kg/mm^2) and an ultimate tensile stress (36 to 45 kg/mm^2) of 56,000 psi. This alloy has considerable ductility and quite reasonable stress-corrosion resistance, i.e., better stress-corrosion resistance than one of the standard alloys used in Germany (Al-5 Zn-3 Mg). Now they are attempting to find how they can modify this alloy to further improve the strength, while not losing any stress-corrosion resistance. They are shooting for a yield stress of 56,000 psi and an ultimate tensile of 62,000 psi.

I talked to Dr. G. Moritz, who returned to Germany in 1962 after having worked for eight years at the Reynolds Aluminum Company in Virginia. While there, he developed an ingot mold for continuous casting such that the continuous cast surface was very smooth and the ingot then did not require scalping prior to extrusion. This mold is covered in US Patent 2983972. He is now working on other modifications of this type of mold so as to make an even better surface, and is hoping to get sufficient new information and new developments to obtain a German patent.

I talked to Herr Scharf, who is mainly responsible for mechanical processing problems, and Dr. G. Ibe, who until recently worked in Prof. Lücke's group at the Technische Hochschule, Aachen. These two men are now deeply concerned with a problem of gas bubbles developing in thinly rolled sheet of unalloyed aluminum (~99.99%). When this is annealed at reasonably high temperatures, bubbles are seen to form which, of course, in a very thin sheet are especially disastrous. They have found that when the bubbles are removed and the material underneath is etched, there are square or triangular etch pits which are apparently crystallographic. They suspect that hydrogen is the culprit. They suspect that these bubbles apparently necleate at inclusions, but they do not know why, because they have some material with lots of hydrogen and many inclusions where there has been no nucleation and other materials with low hydrogen where bubbles have formed.

I also talked to Dr. W. Ibe about the research of his own group, which seemed to be the only wholly basic research group in the Institute. He told me that the crystallographic section had previously been concerned with investigations of minerals. They are now turning to metals, doing research on electron-microscopy on thin foils, precipitation hardening, vacancy clusters, and in particular, looking for the nucleation site for the bubbles mentioned above, which they are quite certain are hydrogen bubbles.

Ibe is beginning a program to study yield points and the Portevin-Le Chatlier Effect in Al-Mg alloys, and is presently growing single crystals of these alloys by the strain anneal technique. He also intends to build a low-frequency torsional pendulum to study the peaks in the same Al-Mg alloy. With the electron microscope, he intends to study dislocation configurations and vacancy condensation in Al-Mg alloys.

I would like to conclude this section by pointing out that this Laboratory is a commercial organization, and the people are considerably more close-mouthed than university people might be, and understandably so. However, this point is important because it explains why some information (on say specific stress-corrosion susceptibility) is missing from this report and other information may seem to be sketchy. This theme also applies below.

BATTELLE INSTITUT e. V., FRANKFURT/MAIN

I first spoke to Prof. Dr. Max Barnick, the Director of the Institute. Barnick was very friendly; however, he made it very clear that the operation of Battelle, Frankfurt was different from some of the other Battelles in that all of the work, with very few exceptions, was done under contract to private corporations and could not be discussed except in very general terms. I visited mainly within the Metallurgical Science and Technology Department with a single excursion into Ceramics. I spoke with Dr. Paul Esslinger about splat cooling, Dr. W. Weidemann on fatigue, Dr. J. Winter on Cr, Ti and Nb base alloy development work, Mr. Schärwachter on deformation and flow studies of T. D. nickel and Dr. J. Nixdorf about composite materials.

Schärwachter has been working in fairly close contact with Dr. B. A. Wilcox at Battelle, Columbus. Wilcox has been studying the mechanism of the yield behavior and Schärwachter has been studying the flow stress of T. D. nickel. He finds that the flow stress is proportional to the square root of the dislocation density which seems to verify the recent theory of Mr. M. F. Ashby (Phil.Mag 14, 1157, 1966). Schärwachter also has pictures taken in the electron microscope of the punched out loops that would be predicted by Ashby's theory and this also helps in verification. Schärwachter next wants to study the work hardening behavior of pure nickel and T. D. nickel, both having the same grain size, in order to be able to separate the behavior of the pure nickel without the dispersant from that of the T. D. nickel, leaving, he hopes, purely the effect of the dispersant, which would provide a direct check on Ashby's hypothesis.

Winter is in charge of the group that works on alloy development. He and a Frau Schmid are doing some work on chromium. They have alloyed chromium with group eight metals, and by doing so they have lowered the ductile-brittle transition temperature to about 100°C (beginning with ordinary electrolytic chromium). They are using mainly Fe, Co and Ni as additives to the chromium, but there are some other additions which are apparently critical, about which Winter could not talk. They have found that these alloys can be used at 1000°C for 1000 hours without any adverse effects as far as the properties of the material at temperature are concerned. However, these materials, as are all other chromium alloys, are brittle when brought down to room temperature.

They have also found that by using Ti-Al-Nb alloys as a basis (this, incidentally, is the work of Frau Prinzbach) they could also obtain very interesting properties in this system. They are working on the quasi-binary between Ti and niobium aluminide ($NbAl_3$). They have found, contrary to what other people have found, more than one intermetallic compound on this quasi-binary. It is apparently a kinetic situation; after a long time at high temperatures these compounds show themselves. They found, for example, that the highest intermetallic compound on

this quasi-binary apparently has no strain-rate sensitivity and that it is possible to use this material for 100 hours at 900°C without deterioration. They also found that other alloy additions could drastically shorten the amount of time required at high temperatures to bring the intermetallic out of solution. The alloy is basically Ti-15.5 Al-18 Nb with a whole range of additions, depending on what it is they want to do with it. The oxidation properties of this material are quite good in the range 800-1000°C; about the same as the best of the nickel-based super-alloys. They were of the opinion that the corrosion resistance is better than the usual alloys, but still possibly not good enough. The strength of this material is about 118,000 psi at 600°C dropping to 56,000 psi at 800°C and more rapidly thereafter.

Esslinger is working with Winter on dispersion strengthening in aluminum alloys, which they are trying to make by splat cooling techniques. These alloys are basically Al-5 Cr with Mg or Si or other materials which normally do not have a high solubility in aluminum, but which can be kept in solid solution by splat cooling. The first technique they used was a device based on levitation melting. At the appropriate time the coils to the levitation melting furnace are shut off and the melt drops straight down. As it does so, it actuates an electric eye which triggers two broad plates timed to slam together so that they actually catch the drop, squeezing it out into a very thin sheet and also providing two large heat sinks to extract the heat. The Al-Cr alloys are quite strong and a low-temperature heat treatment apparently brings out the dispersants which then act to strengthen the material.

They have, however, developed another technique for preparing these alloys which they could not talk about in any detail at all, but which does look very interesting. This is a direct production of rapidly solidified materials using a technique of rolling directly from the melt. They call this liquid-metal rolling and, apparently, if the rolls are big enough and can be kept cool enough, one is able to roll directly from the liquid. If the rolls are about 1 mm apart, the cooling rate is about 5000°C/sec, which is not quite enough for most splat cooling; but if the rolls are of the order of 0.6 mm apart, then one obtains the 10,000 °C/sec cooling rate required to get a greater than normal concentration of alloys in solution, the same as one gets in splat cooling.

Weidemann has been working almost exclusively on the use of modern X-ray techniques to predict the initiation of a fatigue crack. These techniques involve using a mocrofocus camera to gather considerable data and the analysis of the data to give an indication of the dislocation density at some points, the number of cells or the area of cell boundary, etc. By knowing the full fatigue behavior of this material, Weidemann hopes to be able to predict when and where a

fatigue crack will originate. He insisted that he was developing a technique to predict "fatigue failure," and had generated great enthusiasm at Battelle. I pointed out, however, that while he could possibly develop techniques to predict crack initiation in the surface layer of grains, he could do nothing with these techniques to predict which fatigue cracks would penetrate a grain boundary and when, and which cracks would grow and cause failure. It was all a semantic problem, of course; as far as he was concerned the specimen had "failed" when the first crack had formed.

Lastly, at Battelle, I talked to Dr. J. Nixdorf, who has been working on high-temperature materials such as carbides and borides, on high-temperature reactions and also on filaments and composites. His work in composites has been mainly with Taylor wires (which are drawn at very high speeds through a very steep temperature gradient after the wire is first sealed in glass). When he used pure metals -- silver, gold, copper, nickel, etc. -- the highest strength he was able to achieve was 280 kg/mm^2 ($\sim$400,000 psi) for these very fine wires only a few microns in diameter. On the other hand, using maraging steel, they are able to get values in the range 300-400 kg/mm^2 (up to 560,000 psi). They are also able (with 18-8 stainless steels) to obtain a wire that shows a completely brittle fracture or a wire that shows considerable plastic deformation by changing the processing conditions. They are now working on silicate matrices with tungsten wires. It must not be forgotten that these wires (as drawn) are coated with glass. If one wishes to use the wires to stiffen or to strengthen glass, life is simple; but if one wishes to use the wires in some other system, then the glass must be removed. This can be done with ultrasonics, but it is difficult, and although the wires themselves look to be very promising, the business of having them in the glass is quite a problem. The maraging steel filaments have a high modulus and a high strength, and should be very good for use in resin matrices where they have the advantage that they can possibly be manufactured almost as cheaply and probably in longer lengths than can carbon filaments. Nixdorf's results have just appeared in <u>Draht-Welt</u> <u>53</u>, (10), 696 (1967).

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N.A.	N.A.

13. ABSTRACT

Research in physical metallurgy and solid state physics in four research laboratories in Germany are described. Two commercial and two not-for-profit laboratories are covered.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Metallurgical Laboratories						
Fatigue (Mechanics)						
Creep						
Stress-Rupture						
Fe-Ni Martensite						
Electron Microscopy						
Alloy Development						
Stress-Corrosion						
Composite Materials						

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